Integrated on-farm crop diagnosis of upland rice yields in northern Thailand

The problem

• In Southeast Asia, swidden cultivation of upland rice (UR) is still an important component of remote montane farming sytems, but yields in farmers' fields are generally low (1-1.5 t ha^{-1}) and quite variable.

• Under no-input cropping systems, local UR cultivars display yield potentials of 3 and 4 t ha^{-1} for early and late varieties, respectively (Van Keer et al. 1998). But such potentials are seldom reached due to the multiple interacting limiting factors characteristic of the unfavorable upland rice ecosystem.

• To reduce yield gaps, identifying and ranking these limiting factors and understanding their effects on UR crop functioning are a prerequisite to setting research priorities for improving current practices.

Research objectives

• To date and quantify UR yield differentiation under actual farmers' circumstances and management practices,

• To characterize UR environmental conditions and farmers' practices along the whole crop cycle,

• To identify, rank, and understand the main environmental and cropping system variables influencing UR crop production and causing major yield limitations.

The on-farm diagnostic survey for data collection and analysis

• A 4-year (1993-96) on-farm survey covering an extensive range of UR crop situations was conducted in a single highland village.

• Data on crop population status for two contrasting types of local UR cultivars, crop environmental conditions, and cropping practices were obtained through regular monitoring of 432 squares (1 m^2 each) delimited at crop emergence in 63 farmers' fields.

• 'Phase realisation indices', which synthesize the effects of crop constraints during a given phase of UR yield buildup (Wey et al. 1998), were calculated and distribution patterns analyzed to assess the relative importance of successive growth phases in UR yield determination,

• To identify and to rank causes of UR yield differentiation, a principal component analysis with instrumental variables (PCAIV, Lebreton et al. 1991) was carried out on 1993-96 pooled data as well as for individual year subdatasets.

Monitoring squares replicated in a homogeneous zone of a UR field

The study site

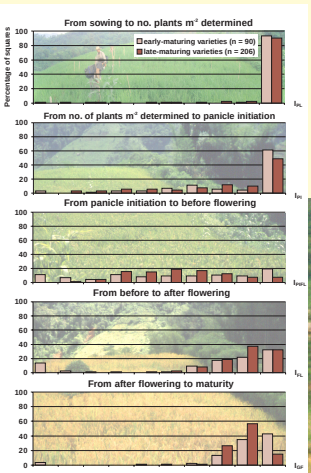
Mae Haeng, a highland Lahu village (600-800 amsl) in northwestern Thailand, is characterized by:
• A monsoon climate, a strong relief, deep granitic soils with clay-loamy texture and medium chemical fertility, heterogeneous (2- to 10-year-old) types of fallow vegetation, and a wide range of weed species, diseases, and insect or other animal pests.
• Traditional swidden cultivation practices in UR no-input cropping systems with only gradually diversifying weed control practices (adoption of hoe tillage and NaCl applications as a herbicide).

Dating and ranking the periods of yield differentiation

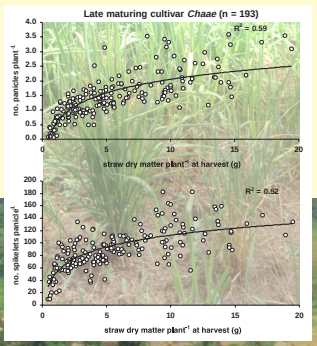
• For the reproductive phase, frequency distributions of phase realisation indices pinpoint panicle formation and spikelet differentiation as key periods of yield differentiation.

• During the vegetative period, poor crop biomass accumulation was of greater importance than low plant density. Vegetative biomass accumulation per plant influenced panicle and spikelet formation, but not spikelet fertilisation or grain filling (data not shown).

Frequency distribution of the successive phase realisation indices of each growth phase for early and late UR cultivars. 1993-96 pooled data.



Relationships between biomass accumulation and UR no. of panicles plant^{-1} and no. of spikelets panicle^{-1} in Mae Haeng. 1993-96 pooled data.

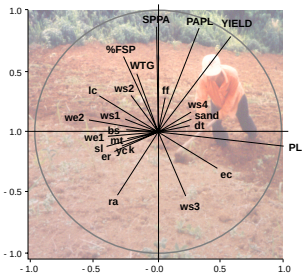


Identifying and grading the causes of yield differentiation

• The analysis of pooled data reveals strong negative relationships for (i) plant density vs weed competition and late-maturing cultivars (having lower sowing densities); (ii) no. of panicles $plant^{-1}$ and no. of spikelets $panicle^{-1}$ vs rice root aphid infestation; (iii) percentage of filled spikelets and 1000-grain weight vs 1995 wet season (dry spells). Weak negative relationships were found for no. of panicles $plant^{-1}$ vs slope angle, erosion, no. of successive UR crops, and early weed stress.

• The analysis of individual year subdatasets isolated rice root aphid infestation as the single major limiting factor having a strong and consistent effect on final UR grain yield.

Plane of PCAIV first two axes showing the relationships among UR yield components, crop environmental conditions, and crop management practices. Mae Haeng, pooled data for 1993-96.



Crop growth variables (at harvest): PL = no. of plants m^{-2}; PAPL = no. of panicles $plant^{-1}$; SPPA = no. of spikelets $panicle^{-1}$; %FSP = percentage of filled spikelets; WTG = 1000-g weight. **Crop environment and crop management variables**: ec, lc = early, late cultivars; mt, dt = minimum, deeper tillage; yc = no. of successive years of UR cultivation; ff, bf, gf = forest, bamboo, grass fallows; ws1, ws2, ws3, ws4 = 1993, 1994, 1995, 1996 wet seasons; sl = slope angle; er = severity of soil erosion; sa = percentage of sand; ph = pH; som = soil organic matter; pav = available P; camg = soil Ca+Mg content; k = soil K content; we1, we2 = cumulated area under the weed cover curve for 0 to 60 DAS and for 60 DAS to harvest respectively; bs = degree of brown spot infestation; ra = degree of rice root aphid infestation.

Hierarchy of factors/conditions influencing UR yield buildup based on the results of PCAIV analysis for each cropping year and pooled data. Mae Haeng, 1993-96.

Year	1993 WS		1994 WS		1995 WS		1996 WS		1993-1996 WS	
Relationship	-	+	-	+	-	+	-	+	-	+
No. plants m^{-2}	**lc** er we1, we2 mt, sl	**ec** sa, dt	**we2, lc** we1 yc, ff	ec	**ra**, we2 we1 er, yc		**we1**, we2 camg k, yc lc	ec	**we2** **lv**	**ev** dt
No. panicles $plant^{-1}$	**ra** we1, we2 camg ph, bf mt, sl k	sa, dt	**er** k ra, bs camg pav		**ra**, we2 gf er, yc we1		**er** **ra** **sl/mt** camg k, yc	**dt**	**ra** ws3 er, sl we1, we3 yc mt	ff
No. spikelets $panicle^{-1}$	**ra** we1, we2 camg ph, bf mt, sl	ff	er k ra, bs camg pav		**ec** gf lc ra, we2	camg sl,	ra mt er		**ra** **ws3** ec er, sl yc	
% Filled spikelets	ec	lc			**ec** gf	camg lc			**ws3** ec	lc ws2
1000-grain weight					lc we1	ec			**ws3** ec	lc ws2
Inertia of axes 1-2	84 %		87 %		70 %		75 %		84 %	
Pertinence of PCAIV	63 %		67 %		52 %		79 %		37 %	

** Boldface indicates strongest relationships*

Conclusions

• UR yield differentiation was found to occur mainly during (i) biomass accumulation in the vegetative phase and (ii) the early part of the reproductive phase.

• The results of this agronomic survey support the validity of several common hypotheses on UR limiting factors (weed competition, drought stress, soil erosion). No important fallow effect was found and no major soil nutrient limiting factor was diagnosed. Finally, this analysis showed that more attention should be paid to soil-borne UR pests when prioritizing issues for the improvement of UR-based cropping systems in the northern Thailand highlands.

References

• LEBRETON J.D., SABATIER R., BANCO G. and A.M. BACOU, 1991. Principal component and correspondence analyses with respect to instrumental variables: an overview of their roles in studies of structure – activity and species – environment relationships. In: Applied Multivariate Analysis in SAR and Environment Studies, ECSC, EEC, EAEC, Brussels and Luxembourg. 85-114.

• VAN KEER K., TREBUIL G., COURTOIS B. and C. VEJPAS, 1998. On-farm characterization of upland rice varieties in north Thailand. International Rice Research Notes, 23:3, 21-22.

• WEY J., OLIVER R., MANICHON H. and P. SIBAND , 1998. Analysis of local limitations to maize yield under tropical conditions. Agronomie 18, 545-561.

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Panoramic view of Mae Haeng village territory, Fang district, Chiang Mai province, upper northern Thailand.